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The Impact of Accurate Distances on UV Spectroscopy of White Dwarfs and Cataclysmic Variables

Paul E. Barrett[*] and Patrick Godon[†,**]

[*] *US Naval Observatory, 3450 Massachusetts Ave., NW, Washington, DC 20392*
[†] *Villanova University, 800 Lancaster Ave., Villanova, PA 19085*
[**] *Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218*

Abstract. J-MAPS and Gaia are two asterometry missions to be launched in 2012. The positions of stars brighter than 15 magnitude will be measured to accuracies of better than one milli-arcsecond and 25 micro-arcseconds, respectively. Accurate distances (< few percent) will constrain the luminosity and hence, effective temperature, radius and mass of isolated white dwarfs. With a sufficiently large sample, evolutionary models can be tested. For cataclysmic variables (CVs), evolutionary models can also be tested, particularly for dwarf novae in quiescence where the white dwarf is detected. By measuring the T_{eff} of the white dwarf, the long-term accretion rate of the binary can be estimated and compared with the expected accretion rate of magnetic braking for CVs above the period gap (> 3 hr) and gravitational braking for those below the gap (< 2 hr). For nova-like systems, whose luminosity is dominated by the accretion disk and affected by interstellar extinction and reddening, accurate distances can help constrain the temperature profile of the disk.

Keywords: distances:parallaxes, spectroscopy: ultraviolet, white dwarfs, cataclysmic variables, accretion disks
PACS: 97.10.Vm, 97.10.Ex, 97.20.Rp, 97.80.Gm

INTRODUCTION

Gaia

Leveraging upon the highly successful Hipparcos satellite, Gaia is an astrophysics driven mission, which utilizes the twin field-of-view scanning concept, updated with modern technology, to achieve significant gains in astrometric precision. Funded by the European Space Agency and expected to launch in early 2012, Gaia employs two 1.45×0.5 m apertures with a 35 m focal length focused on a common 106 CCD gigapixel focal plane. In addition to producing astrometric parameters for objects to 20th magnitude, Gaia will also provide photometric and a few km s^{-1} level radial velocity data. The final Gaia catalog, anticipated to be released in 2020, is expected to provide astrometric accuracies at the 25 micro-arcsecond level for stars brighter than 15th magnitude, and contain on the order of a billion objects. With science operations continuing for 5–6 years, the Gaia program intends to provide intermediate releases of the Gaia star catalog, perhaps at the three-year mark.

CP1135, *Future Directions in Ultraviolet Spectroscopy*, edited by G. Sonneborn, M. Van Steenberg, H. W. Moos, and W. P. Blair
2009 American Institute of Physics 978-0-7354-0672-8/09/$25.00

J-MAPS

The Joint Milli-Arcsecond Pathfinder Survey (J-MAPS) is a microsatellite mission intended to update Hipparcos astrometry. With its single aperture 19 cm telescope, J-MAPS will access not only the brightest stars observed by Hipparcos, but also extend Hipparcos level milli-arcsecond astrometry to 15th magnitude stars. Combining J-MAPS and Hipparcos data will provide proper motion information at the level of a few tens of micro-arcseconds per year for stars brighter than 11 magnitude in the V band. Using a stare-mode concept, J-MAPS can integrate longer for specific fields on the sky, which allows the J-MAPS star catalog to tie directly to an extragalactic reference frame by observing quasars that are part of the ICRF. The J-MAPS program is in the design and development stage, with an expected launch in early 2012.

WHITE DWARFS

Asteroseismology is a powerful probe of the internal structure of stars and a test of the predictions of stellar evolution. Four instability strips in the HR diagram are associated with planetary nebulae nuclei (PNN) and white dwarfs (WDs). The first instability strip occurs during the high luminosity planetary nebula phase. The second is during the pre-WD stars of the PG 1159 spectral type, which are direct descendants of many PNN. The third and fourth instability strips are associated with the pulsating hydrogen (DAV or ZZ Ceti stars) and helium (DBV) WDs. Except for the DAVs, none of these instability strips are pure, i.e., some non-variable stars are found within each region. Why this is the case is still not known.

The pulsating PG 1159-type star RXJ 2117+3412 is a good example of the need for accurate distances. An analysis of the spacings between its multiple periods gives a total mass, $M = 0.56^{+0.02}_{-0.04}\ M_{\odot}$ (Vauclair *et al.* 2002). This mass and the atmospheric parameters (log g, T_{eff}) give a distance accurate to within only 30%, i.e., 760^{+220}_{-225} pc. Gaia will provide distances to this PNN to $< 1\%$, placing a tight constraint on the stellar luminosity and hence, on the stellar mass and atmospheric parameters. Since astrometry provides an unambiguous distance, i.e., not dependent upon atmospheric models, any changes to the star's UV luminosity can be directly attributed to evolutionary changes, since most of the UV opacity is due to heavy elements. It is possible that photometric changes can be detected over a couple of decades as the excess He-rich envelope is shed within about 10^5 yr, exposing the heavier elements underneath.

CATACLYSMIC VARIABLES

Multiwavelength, multi-component, synthetic spectral models of the far ultraviolet spectra of cataclysmic variables (CVs) coupled with evolutionary simulations are yielding deeper insight into the physical structure of CV boundary layers, angular momentum transfer, and long-term heating during mass accretion onto their WD primaries. Similar to the situation for WDs, these detailed analyses are limited by our knowledge of two fundamental parameters: the measured interstellar extinction along the line-of-sight and

the distance to the CV. For example, the FUSE survey of high declination dwarf novae (DNe; Godon, *et al.* 2009) presents the spectral analysis of eight systems observed during the Cycle 7 observing period. The selective extinction, $E_{(B-V)}$, for the sample is ≤ 0.30 with an estimated uncertainty of 50% or more for some systems. This translates into comparable uncertainties in the estimated T_{eff} of the WD atmosphere and disk, since the extinction reduces the slope of the continuum flux, and ultimately the CV's luminosity and distance. The preferred method of measuring the extinction is to observe the broad 2175 Å absorption feature in the near UV. Most of the extinction estimates for CVs are based on observations by the IUE, because of its broad wavelength coverage, medium resolution and easy accessibility. However, many of these measurements are only rough estimates ($\sim$ 50%) because of the low quality of the data. The STIS and COS instruments on HST have the capability to vastly improve these measurements, but observation time on these instruments is severely limited. UV grism observations using Swift and Galex are an option.

Current efforts on understanding the long-term evolution of CVs have focused on DNe in quiescence, where the WD contributes a significant amount of the flux. Synthetic spectral models are fit to the WD component to determine its $\log g$ and T_{eff} as is done for isolated WDs. The relative contribution of the flux from the disk and WD can then be used to determine the T_{eff} and accretion rate, $\dot{M}$, of the disk, which can then be compared to evolutionary models. For systems below the period gap ($\lessdot$ 2 hr), the binary evolution is dependent on the strength of gravitational braking. For nova-like (NLs) systems which resemble DNe in continuous outburst, the WD is usually not detected. Physical parameters derived from spectral model fits to the continuum are therefore less certain, since they depend sensitively on the assumed extinction. Accurate extinction measurements coupled with accurate distances (< few percent) provided by J-MAPS and Gaia can provide tight constraints on the luminosity and hence, T_{eff} and $\dot{M}$ of the disk. Most of these systems have orbital periods above the period ($\gtrdot$ 3 hr) gap, where magnetic braking is important. Finally, most synthetic spectral fits to accretion disk spectra assume a Shakura-Sunyaev accretion disk model. Testing the accuracy of this assumption is difficult without accurate extinction and distance measurements.

In summary, the astrometric satellites, J-MAPS and Gaia, will tightly constrain the absolute luminosities of WDs and CVs, making it possible to test the accuracy of the stellar atmosphere and evolution models of these systems.

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